International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Assessment Instrument of Scientific Literacy Skills on Motion and Simple Machines Learning Based on Nature of Science

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Abstract

Natural science learning train students various skills in the face of 4.0 industry revolution challenge. One of the skills that need to be developed is scientific literacy skills. The scientific literacy skills level can be known or measured using appropriate assessment instruments. This study aimed produce assessment instruments can measure the scientific literacy skills and know scientific literacy skills level of 8th grade students in Junior High School 2 Pare. The research method was descriptive quantitative with instrument development model of Mardapi (2012). The theoretical and empirical experiments of scientific literacy skills instruments get eligible criteria for use based on Aiken's validity and Rasch model analysis. Scientific literacy skills level of 8th grade students Junior High School 2 Pare's students is 20% students have high level, 72,5% average level, and 7.5% low level.

Keywords: scientific literacy skills; assessment instrument; nature of science; motion and simple machines course.

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1. Introduction

Technology development recently has reached the 4.0 industrial revolution. The 4.0 industrial revolution is characterized by the development of robots and artificial intelligence faster than predicted. These development take large impacts, particularly on the future of job. Some jobs will disappear and be replaced by robots with high intelligence. This challenge needs to be faced by preparing young people who are ready to compete with robots. Education plays an important role in training young people to compete in the era of 4.0 industrial revolution. Nasir explained that we need a curriculum with a new orientation in providing effective education for students. A new orientation that can be done in education is training some skills that students need to face of 4.0 industrial revolution

One of skills students need is literacy skills. According to Aoun [1], there are three literacy skills that must be mastered. They are data literation, tecnology literation, and human literation. Middle school is the education level that can train the data literation skills. Data literation includes mastery to read, analyze, and use information. These skills can be trained on natural science learning by giving students information or daily issues related to the scientific world. The literacy skills in science learning are often known as the scientific literacy skills.

The scientific literacy skills need to be placed as an important natural science education destination [20]. Treacy and his colleagues [21] also state that scientific literacy becomes very important for students as a key to face the challenges of globalization development. Scientific literacy is very important because science and technology are involved in every aspect of life [13]. Students who have a high scientific literacy skill level will be fast to know about condition or daily issues around them. They can relate the problem to the theory or concept they acquired in school.

OECD [14] states the scientific literacy skills is the ability to use scientific knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw conclusions based on scientific evidence. Whittingham and his colleagues [22] also explains that the literacy skills is related to the ability like apply, synthesize and evaluate existing information effectively. Bybee [3] defines scientific literacy is basis of natural science education. Therefore, the scientific literacy skills are the ability to analyze scientific information to gain new knowledge through natural science learning.

Scientific literacy has four domains consisting of context, scientific knowledge, attitude and competency. The domain is used in the students' scientific literacy skills assessment. The domain of context, scientific knowledge, and competence is a domain that measures the ability of science literacy in terms of students' cognitive skills. OECD [14] explains the domain of competency has three aspects: (1) identifying scientific issues (2) explaining phenomena scientifically, and (3) using scientific evidence. These three aspects are expanded to be indicators in table 1 below.

Indicators in scientific literacy skills are appropriate with several aspects and indicators in the nature of science (NOS). Chiappetta [4] says that aspects of the nature of science consists of (1) the body of knowledge, (2) the

way of investigating, (3) the way of thinking, and (4) the interaction of science, technology, and society. Aspects of the NOS is the body of knowledge has similarities with aspects of scientific literacy is identifying scientific issues. While the NOS aspect of the way of thinking has similarities with aspects of scientific literacy is explaining phenomena scientifically and using scientific evidence. Based on these descriptions, the scientific literacy skills have covered several aspects of NOS required in natural science learning.

Table 1: Aspects and Indicators of Scientific Literacy Competency Domains

No.	Aspects	Indicators
1	Identifying scientific issues	a. Recognising issues that are possible to investigate scientifically b. Identifying keywords to search for scientific information c. Recognising the key features of a scientific investigation
2	Explaining phenomena scientifically	a. Applying knowledge of science in a given situation b. Describing phenomena scientifically and predicting changes c. Identifying appropriate descriptions, explanations, and predictions
3	Using scientific evidence	a. Interpreting scientific evidence and maing conclusions b. Identifying the assumptions, evidence, and reasoning behind conclusion c. Explaining feedback toward scientific conclusion

(OECD, 2013)

Gormally and his colleagues [7] also explains scientific literacy skills have two important aspects. These aspects consist of (1) understanding inquiry methods that lead to scientific knowledge, and (2) organizing, analyzing and interpreting quantitative data and scientific information. Based on aspects and indicators, scientific literacy skills can be categorized as a high order thinking skills. This is similar with Setyorini's statement [16] which says that high order thinking skills includes the individual's thinking skills that has reached the level of analysis, evaluate, and synthesis.

Some aspects of scientific literacy skills, which have been described, can be used in the assessment of scientific literacy skills to determine the development of literacy skills possessed by students. Assessment of the scientific literacy skills needs to be designed maximally so can measure student skills appropriately. The use of assessment instruments that measure the development of students' scientific literacy skills can help teachers to provide an optimal learning experience for students [9]. Gettinger [6] states that teachers should be able to use the results of literacy assessment effectively so as to adapt learning activities for students with low literacy skills.

According to research Brink [2], teachers often do not use the test results well. Whereas the students assessment results can be used to arrange content of natural science learning and adapt it to best learning strategies and methods as well as to know the level of students' scientific literacy skills through the natural science learning that has been given. Mustofa's research results [11] also stated that teachers have not fully understood the implementation of the 2013 curriculum assessment due to the limited sample of test assessment. The results of interviews conducted by researcher at 5 middle school teachers also stated that teachers have difficulty measuring the scientific literacy skills from students because of the unavailability of item examples of scientific literacy in appropriate with natural science subject taught to students. It is necessary to develop assessment instruments to measure the scientific literacy skills that valid, reliable and based on nature of science.

Measurement of students' scientific literacy skills can be done by using an assessment instrument consisting of several items of test questions. The appropriate form of scientific literacy skills test for middle school students is a multiple-choice test. Multiple choice tests can provide more in-depth information about what students know and can do [5] and facilitate feedback from a variety of learning methods used in the classroom [8]. From these statements, multiple-choice tests can be used to measure high-order skills such as scientific literacy skills.

Some considerations also form the basis for the arrangement of scientific literacy skills assessment instrument for middle school students. In addition to the test form, the arrangement of assessment instruments also consider the natural science subject will be tested. The natural science subject tested must be related to the problems of daily life. The students' age to be measured by scientific literacy skills also needs to be considered. According to Pantiwati [15], the scientific literacy skills are very well observed when students aged between 10 to 15 years. At that age, students come in the transitional level from the concrete thinking level to the abstract thinking level so tstudents have been able to use their scientific literacy skills. Based on these considerations, researchers developed an assessment instrument of scientific literacy skills based on NOS at force and simple machines subject to measure students' scientific literacy skills. This research was conducted on natural science learning of middle school with the aim to: (1) produce assessment instruments that can measure scientific literacy skills in terms of theoretical and empirical appropriateness of the instrument; and (2) to know the level of scientific literacy skills based on item analysis.

2. Material and Methods

This research is a research and development using model of instrument development according to Mardapi [10]. The instrument development model consists of 8 stages: arranging test specifications, reviewing tests, conducting initial test, analyzing test items, revising test items, conducting final tests, and interpreting test results. The main product tested in this development study is an assessment instrument that can measure scientific literacy skills. Initial test were conducted in six classes from three different schools. They are SMP N 2 Pare, SMP N 1 Badas, and SMP N 2 Puncu. The final test was carried out in VIII-D grade of SMP N 2 Pare.

The initial test subjects in this study were students of VIII class as many as 226 students. The final test subjects were 40 students. Data collection techniques used in this study were interviews, questionnaires, and tests. The data collection instruments used in this study was interview guides, validation sheets, and assessment

instruments of scientific literacy skills. Data analysis technique used descriptive qualitative and quantitative analysis. Qualitative analysis aims to determine quality of product theoretically. Quantitative analysis aims to determine quality of products empirically. Analysis of validation results theoretically using Aiken's validity content. Analysis of empirical test results using Rasch model with Winsteps 3.73 software.

3. Result and Discussion

Development for arranging assessment instruments of scientific literacy skills is conducted through two stages, arranging test specifications and reviewing tests. The assessment instrument specifications consist of assessment objectives, assessment manual, test item distribution, and length of tests. Aspects and indicators of the scientific literacy skills used in arranging assessment manual are derived from OECD. Indicators of scientific literacy skills used in the development of the item include all indicators developed by the OECD. All of these indicators are suitable for further development as an indicator of force and simple machines subject. Assessment manual includes aspects and indicators of scientific literacy skills, item indicators, item numbers, subject and answer keys.

The number of item types for the scientific literacy skills consists of two item types: A and B types. Each item types has 20 questions with 4 choices of answers (ABCD). The number of anchor questions is 4 questions. The time work given for each types is 60 minutes. Based on specification aspects of the assessment instrument, the initial draft of assessment instrument is developed. The initial draft of the instrument that has been arranged is then reviewed and validated by the validator to determine item validity theoretically. Validator consists of subject lecturers, evaluation lecturers, practitioners (teachers), and peers.

Assessment instrument of scientific literacy skills is assessed by the validator through the validation sheet. This validation sheet has 13 aspects of assessment instrumnet. Score of all validators are analyzed by the aiken's validity (V) equation. If the score is $V \geq 0.86$, then the item is said to be valid. Based on the results of aiken analysis, all the items, 32 main questions and 4 anchor questions, in A and B item types received valid criteria. A valid criterion states that the item has 60% more from the criteria for the arrange of items based on seven validators. The items get advice from the validator so that it can be fixed in appropriate with the aspect of validation that has not been fulfilled. There are 37 items that need to be revised consisting of 18 items from A type and 19 items from B type. 4 anchor items also need to be revised in order to be used to measure students's scientific literacy skills well. The revised items are then rearrange to be the initial product of assessment instrument of scientific literacy skills. The initial product will be used in initial test to obtain validity and reliability values empirically as well as know characteristics of items.

Initial test is done through two stages of development include (1) conducting initial test, and (2) analyzing test items. Initial test were conducted in three schools with 226 students. The test results, in the form of student answers, were analyzed using the Rasch model with Winsteps 3.73 to find out the feasibility of the instrument and the characteristics of items. Instrument feasibility can be known from the value of item fit and reliability. Characteristics of items can be known from difficulty item value or item measure.

The quality of item fit can be seen in the item fit output from Winsteps.

The level of a fit item can be determined by three value criteria: (1) the value of outfit mean square (MNSQ) received:

0,5<MNSQ<1,5; (2) the value of outfit z-standard (ZTSD) received: -2,0 <ZTSD <+2,0; and (3) the value of point measure correlation received: 0,4 <Pt. Measur Corr <0.85. If a item does not get more than one of the above criteria, the item is said to be unfit or unusable or needs to be replaced. The results of the item fit analysis for A item type are presented in table 2.

Table 2: Results of Item Fit Analysis for A Item Type

No	No. Item	Item Fit Criteria				Result
		Outfit MNSQ	Outfit ZTSD	Pt. Corr	Measure	
1	A14	1,26	1,1	0,15		fit
2	A17	1,23	1,1	0,18		fit
3	A6	1,18	0,9	0,32		fit
4	A11	1,17	1,7	0,24		fit
5	A15	1,12	1,1	0,24		fit
6	A18	1,03	0,2	0,24		fit
7	A19	1,09	1,0	0,28		fit
8	A7	1,04	0,3	0,25		fit
9	A20	1,04	0,3	0,32		fit
10	A12	0,99	0,0	0,34		fit
11	A16	0,94	-0,5	0,39		fit
12	A1	0,95	-0,3	0,39		fit
13	A13	0,97	-0,1	0,36		fit
14	A8	0,94	-0,6	0,41		fit
15	A9	0,95	-0,3	0,38		fit
16	A10	0,90	-0,9	0,43		fit
17	A3	0,92	-0,7	0,44		fit
18	A5	0,91	0,8	0,47		fit
19	A2	0,75	-2,8	0,59		fit
20	A4	0,73	-2,6	0,59		fit

The result of item fit analysis for B item type is presented in table 3.

Table 3: Results of Item Fit Analysis for B Item Type

No	No. Item	Item Fit Criteria				Result
		Outfit MNSQ	Outfit ZTSD	Pt. Corr	Measure	
1	B12	1,16	1,7	0,23		fit
2	B10	1,15	1,4	0,23		fit
3	B6	1,11	1,2	0,31		fit
4	B16	1,11	0,9	0,27		fit
5	B2	1,10	1,0	0,33		fit
6	B13	1,08	0,7	0,32		fit
7	B19	1,06	0,5	0,28		fit
8	B9	0,98	-0,1	0,32		fit
9	B20	1,02	0,2	0,33		fit
10	B4	1,00	0,0	0,30		fit
11	B7	0,95	-0,3	0,35		fit
12	B15	1,00	0,0	0,36		fit
13	B3	0,98	-0,2	0,37		fit
14	B17	0,97	-0,3	0,39		fit
15	B11	0,92	-0,7	0,44		fit
16	B14	0,90	-0,7	0,44		fit
17	B18	0,89	-1,2	0,46		fit
18	B8	0,87	-1,4	0,47		fit
19	B5	0,78	-1,3	0,48		fit
20	B1	0,83	-1,8	0,51		fit

Based on the results of item fit above, all items in the assessment instrument of A and B item type can be accepted and used to measure the scientific literacy skills of middle school students in 8th grade.

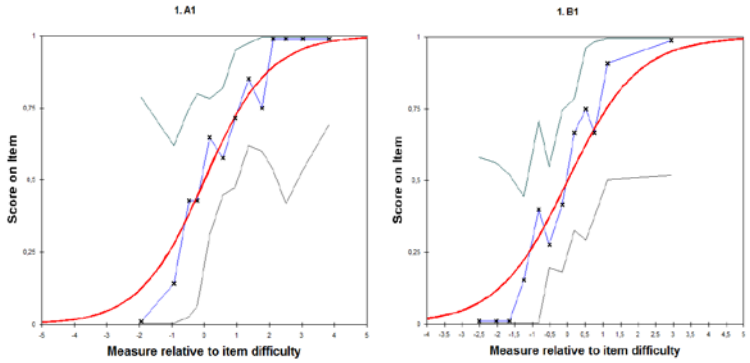

Figure 1: ICC Graph of A1 and B1 item

Analysis of item fit with winsteps also provides illustration in the form of ICC (Item Characteristic Curve) graph

as presented in Figure 1. The graph illustrates the student's answer pattern for scientific literacy skills item in number 1 of A type (A1) and number 1 of B type (B1). The answer pattern of all students is within the limits of the acceptance space of infit and outfit. The results of this graph support item fit analysis with the Rasch model and show that the developed items provide a good answer pattern. The value of reliability assessment instrumen can be known from output summary statistic with Alpha Cronbach (KR-20) reliability. The higher the value of reliability, the higher the level of trust/consistency of the assessment instrument in measuring desired skills. The result of reliability estimation for assessment instrument of A and B type according to Alpha Cronbrach reliability (KR-20) is 0,64 and 0,65. These results indicate that the overall assessment instrument of scientific literacy skills has a good enough reliability. The reliability results of this assessment instrument from initial test also give the result of a graph on test information function (TIF) and standard error measurement (SEM) as follows

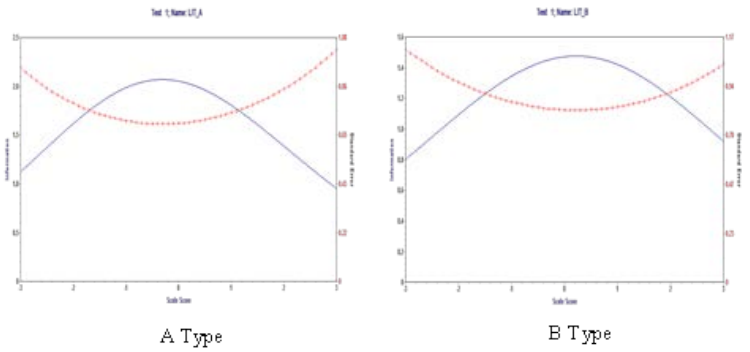

Figure 2: TIF and SEM of A and B Item Type

The graph above shows the shape of the curve increasingly pointed at the center. Sumintono (2015) states that the curve is increasingly pointed in the middle, indicating a good assessment instrument for measuring students with average level skill. Based on the explanation, assessment instruments of A and B item type will provide optimal information when given to students with average level of scientific literacy skills. The items in assessment instrument of scientific literacy skills that are tested can be divided into three categories of item that are easy, medium, and difficult. The easy item has a low (negative) logit value, and the difficult item has a high logit value (positive) exceeds the standard deviation value of the item logit. The analysis of item category based on difficulty level item for A item type with Rasch model is presented in table 4.

Table 4: Result of Item Category for A Item Type

No	Category	Number of item	Total of item	Percentage
1.	$n \geq 0,87$ (difficult)	A14, A6, A18	3	15%
2.	$-0,87 < n < 0,87$ (medium)	A10, A11, A19, A8, A12, A2, A5, A16, A3, A15, A4, A1, A20, A9	14	70%
3.	$n \leq -0,87$ (easy)	A13, A17, A7	3	15%

The results of item category for A item type showed that 20 items consist of 15% of difficult category, 70% for medium category and 15% for easy category. The analysis of item category based on difficulty level item for A item type with Rasch model is presented in table 5.

Table 5: Result of Item Category for B Item Type

No	Category	Number of item	Total of item	Percentage
1.	n ≥ 0,63 (difficult)	B9, B14, B19, B16	4	20%
2.	-0,63 < n < 0,63 (medium)	B10, B2, B18, B1, B6, B20, B3, B15, B12, B8, B17, B11	12	60%
3.	n ≤ -0,63 (easy)	B7, B13, B4, B5	4	20%

The results of item category for A item type showed that 20 items consist of 20% of difficult category, 60% for medium category and 20% for easy category. The proportion of items in A and B item type is sufficiently balanced for assessment instruments. The items are not dominated by item that have a difficult level so it can measure the mastery of students' scientific literacy skills with various skills either low, average, or high level skill.

The results of the scientific literacy skills assessment instrument that have been analyzed with Rasch model are presented in the following item recapitulation.

Table 6: Recapitulation of Scientific Literacy Skills Item

No	Item type	Number of item		
		Fit item	Revision item	Unfit item
1	A type	A1, A2, A3, A4, A5, A6, A7, A8, A9, A12, A13, A16, A17, A18, A19, A20	-	-
2	B type	B5, B6, B7, B8, B9, B10, B11, B12, B13, B16, B17, B18, B19, B20	-	-
3	*Anchor*	A10, A11, A14, A15, B1, B2, B3, B4	-	
Total		40 items	-	-

Based on table 6, the items received or fitted from the initial test phase are 40 items consist of 16 items from A type, 16 items from B type and 8 anchor items. All scientific literacy skills items developed can be accepted or used to measure scientific literacy skills of middle school students in 8th grade.

The revision of assessment instrument conducted after initial test includes repair image and wrong words. Improvement is done to facilitate students in understanding item and rearrange into the final product assessment instrument. The final product is used in final test to determine the level of scientific literacy skills of students in SMP N 2 Pare. The final test subject is students of 8D for about 40 students.

The final test results were analyzed using Rasch model analysis so produce students' scientific literacy skills level. Student grouping analysis based on scientific literacy skills level is presented in Table 7.

Table 7: Scientific Literacy Skills Level of JUNIOR HIGH SCHOOL 2 Pare Students

No	Level of A type	Number of student – A type	Total	Level of B type	Number of student – B type	Total
1.	n ≥ 1,63 (high)	26, 05, 08, 16	4	n ≥ 0,91 (high)	07, 23, 27, 38	4
2.	-1,63 < n < 1,63(average)	21, 13, 28, 35, 02, 12, 34, 36, 01, 20, 24, 25, 33, 26, 40	15	-0,91 < n < 0,91(average)	11, 30, 31, 37, 17, 18, 09, 32, 03, 19, 29, 10, 14, 04	14
3.	n ≤ -1,63 (low)	15	1	n ≤ -0,91 (low)	22, 39	2

Based on table 7, the total of students with scientific literacy skills as whole is 8 high level students (20%), 29 average level students (72.5%), and 3 low level students (7.5%). The grouping indicate that the 8D students of SMP N 2 Pare have average level scientific literacy skills. The results of this study indicate that the assessment instrument developed in the form of multiple choice test can measure scientific literacy skills of middle school students. This result is similar with Sudiatmika (2010) and Bashooir (2017) research which also shows assessment instruments in the form of tests can measure the scientific literacy skills.

4. Conclusion

The results of research and development show that (1) the assessment instrument of scientific literacy skills tested theoretically and empirically obtained feasibility criteria deserves to be used based on Aiken's validity and Rasch model analysis. The assessment instrument in the form of multiple choice test has fulfilled Aiken's validity from validator by obtaining validation value range 0,86 - 1,00 with valid criterion. The assessment instrument of A and B type has 40 items of fit from the Rasch model item fit analysis. The reliability of the assessment instrument of A and B type are 0,64 and 0,65 with good criteria. The difficulty level of item in the assessment instrument of scientific literacy skills with A and B type as whole consist of 17,5% of difficult

category, 65% for medium category and 17,5 % for easy category. These results indicate that the proportion of items in this assessment instrument is more on medium difficulty level items. (2) The level of scientific literacy skills students of JUNIOR HIGH SCHOOL 2 Pare is 20% of students have high level skill, 72.5% of students have average level skill, and 7.5% of students have low level skill.

5. Recommendations

The assessment instrument of scientific literacy skills that developed can be used by junior high school teacher or university student who want to know and measure scientific literacy skills for 8th grade students on motion and simple machine learning.

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